Competency 2.4 **Waste management personnel shall demonstrate a working level knowledge of Department of Energy (DOE) Order 5400.5, *Radiation Protection of the Public and the Environment*.**

1. SUPPORTING KNOWLEDGE AND/OR SKILLS

a. State the Department's policy and discuss the objectives regarding the protection of the public and the environment from radiation as contained in DOE Order 5400.5, *Radiation Protection of the Public and the Environment*.

b. Define the following terms:

- As Low As Reasonably Achievable (ALARA)
- Best available technology (BAT)
- Derived concentration guide (DCG)
- Absorbed dose (D)
- Collective dose equivalent
- Collective effective dose equivalent
- Committed dose equivalent (CDE)
- Committed effective dose equivalent (CEDE)
- Deep dose equivalent
- Dose equivalent (H)
- Effective dose equivalent (EDE)
- Public dose
- Weighting factor (W_T)
- Quality factor (Q)
- Effluent monitoring
- Environmental surveillance
- Protective action guides
- Release of property
- Residual radioactive material

- Settleable solids
- Soil column

c. Given an As Low As Reasonably Achievable (ALARA) plan, discuss the extent to which the minimum factors were addressed.
d. Discuss the public dose limit factors associated with all exposure modes including sources from the management and storage of spent nuclear fuel, high-level wastes, and transuranic wastes at disposal facilities.
e. Discuss the factors waste management personnel must take into consideration regarding the management and control of radioactive materials in liquid discharges and phase-out of soil columns.
f. Given treatment technology data on the discharge of liquid waste to surface waters, determine the available technologies and, given sufficient information on those technologies, determine the best available technology.
g. State the Department's position regarding the continued use of soil columns.
h. State when the best available technology application process shall be used in relation to the discharge of liquid wastes to sanitary sewerage.
i. List and discuss the factors that must be considered pertaining to the release of materials and equipment having residual radioactive material as outlined in DOE Order 5400.5, *Radiation Protection of the Public and the Environment*, Chapter IV, Residual Radioactive Material.

2. SUMMARY

The relevant requirements, interrelationships and importance of the DOE Orders, notices, codes, and regulations listed above are summarized on the next page. Radiation protection personnel have a responsibility to utilize and implement applicable regulations issued by DOE.

NOTE: DOE Order 5400.5 is in the process of being codified under 10 CFR 834.

DOE Order 5400.5, *Radiation Protection of the Public and the Environment*	
Purpose	Protects the public and the environment against undue risk of radiation due to operations of DOE and DOE contractor facilities.
Scope	DOE and DOE contractor facilities
Requirements/ Key Words	<u>Chapter I, General Summary</u> DOE is primarily adopting the ICRP 26/30 system of dose calculation, limitation, etc. The DOE primary standard is 100 mrem effective dose equivalent (EDE) in a year above background to members of the public from all pathways and sources. (This is reduced from the previous primary standard of 500 mrem in a year, since it is already largely being achieved and it follows the International Commission on Radiological Protection [ICRP] recommendation.) <u>Chapter II, Requirements for Radiation Protection of the Public and the Environment</u> The primary limit of 100 mrem EDE in a year is described in detail. The limit includes all pathways and sources and internal and external exposure. It does not include doses received from occupational exposures, naturally occurring background radiation, medical radiation, consumer products, or fallout. If justified, the public dose limit can be temporarily increased to 500 mrem through a request to EH-1. <u>Chapter III, Derived Concentration Guides (DCGs) for Air and Water</u> DCGs are concentrations of a radionuclide in air or water that, under conditions of continuous exposure for one year by one exposure mode (e.g., ingestion of water), would result in an effective dose equivalent of 100 mrem. These are not limits, but tools to be used in meeting the basic requirements. <u>Chapter IV, Residual Radioactive Material</u> Residual Radioactive Material: • Originally issued as guidance for Formerly Utilized Sites Remedial Action Program (FUSRAP) and Surplus Facilities Management Program (SFMP). • Chapter IV of DOE Order 5400.5 now applies DOE-wide. • Basic dose limit is 100 mrem above background effective dose equivalent in a year due to residual radioactive material. It is expected that the potential doses associated with actual or likely use of the released property will be a few mrem or less. This limit applies to all sources and pathways (excluding background and medical). The limits for radon and radon progeny are addressed separately. • Guidelines for residual radioactive material in soil shall be derived by environmental pathway analysis except for thorium (Th) and radium (Ra). The RESRAD computer program is recommended, but alternate procedures are acceptable.

DOE Order 5400.5, *Radiation Protection of the Public and the Environment,* establishes standards and requirements for operations of DOE and its contractors with respect to protection of the public and the environment against undue risk from radiation. The Order is divided into four chapters that discuss the general topics covered in the Order, requirements for radiation protection of the public and the environment, derived concentration guides for air and water, and residual radioactive material.

Chapter I, General Summary

The first chapter serves as a general introduction. The chapter highlights Internal Commission on Radiological Protection (ICRP) recommended methodology, the DOE primary dose standard, the ALARA philosophy, treatment technologies, and compliance with the Order.

Specifically, DOE:

- Adopts the ICRP 26/30 methodology recommended in 1977. (**NOTE**: Since the issuance of DOE Order 5400.5, the ICRP has published new recommendations on radiation protection, ICRP 60.)
- Uses a primary dose standard of 100 mrem in a year. This is an EDE from all sources and all pathways.
- Adopts the ALARA philosophy. This means that in this Order, ALARA is no longer a recommended practice, but rather a required part of the radiation protection program.
- Adopts the BAT as the appropriate level of treatment for liquid wastes at the point of discharge.
- Calls for the phasing out of soil columns to prevent the buildup of contamination in soils and groundwater, thereby protecting the environment.
- Requires compliance with the Order through effluent monitoring, environmental surveillance, computer modeling, and dose conversion factors.

Chapter II, Requirements for Radiation Protection of the Public and the Environment

The primary dose limit for members of the public is 100 mrem EDE in a year from all sources and all pathways. The EDE was originally defined by the ICRP when they introduced a risk-based system in ICRP 26. The EDE allows the summation of external and internal doses. The primary dose limit, therefore, includes exposures from sources external to the body during the year and the committed EDE from radionuclides taken into the body during the year. This limit does not apply, however, to doses from medical exposures and consumer products. The limit does not generally apply to naturally occurring radioactivity and accident conditions. Authorization to exceed the primary standard is possible, but requires approval from DOE officials (EH-1).

Other limits specified in this chapter are:

• Airborne emissions (40 CFR 61)	10 mrem (0.1 mSv) EDE
• Spent nuclear fuel, high-level, and transuranic wastes (40 CFR 191)	25 mrem (0.25 mSv) whole body 75 mrem (0.75 mSv) any organ
• For drinking water (40 CFR 141)	4 mrem (0.04 mSv) EDE at the tap
	5E-9 µCi/ml (Ra-226 + Ra-228) 1.5E-8 µCi/ml gross alpha

The regulation of airborne emissions is required under the Clean Air Act, which, in turn, precipitated the issuance of 40 CFR 61, *National Emission Standards for Hazardous Air Pollutants*. The airborne limit of 10 mrem is based on releases to the atmosphere from routine DOE activities. Exposures from radon-220 (Rn-220), radon-222 (Rn-222), and their progeny are subject to separate DOE limits.

NOTE: The limits for spent nuclear fuel facilities, etc., are not in EDE units since both whole body and organ doses are specified. Simply stated, 40 CFR 191, *Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level, and Transuranic Radioactive Wastes*, was written several years ago using ICRP 2 methodology, which treated external and internal doses separately.

The drinking water limits in this order are based on 40 CFR 141, *National Interim Primary Drinking Water Regulations* (Safe Drinking Water Act), a regulation that was also written prior to the advent of the EDE. However, it is listed here as an EDE because DOE has chosen to do so. The 4-rem limit applies to community water systems that serve at least 15 connections or regularly serve an average of at least 25 individuals daily at least 60 days out of the year.

As stated earlier, the ALARA approach is now required for DOE activities and facilities that could result in public doses. DOE Order 5400.5 lists several factors that should be considered in an ALARA program. Quantitative cost-benefit analyses of many of these of these factors can be both expensive and difficult to evaluate. Therefore, flexibility is given in the Order to perform qualitative ALARA analyses in those instances where doses are well below the limits and requirements of the National Environmental Policy Act (NEPA) have been met. Analyses of a quantitative nature are definitely required, however, when potential doses approach the limit.

To assist DOE personnel and their contractors in the implementation of the ALARA process as it relates to DOE 5400.5 DOE issued *DOE Guidance on the Procedures in Applying the ALARA Process for Compliance With DOE 5400.5* DOE now requires tightened controls on the discharge of liquid effluents from its facilities. The objective is to protect resources such as land, surface water, and groundwater from undue contamination. This has created the need for an evaluation of BAT.

According to the Order, a BAT review is required for liquid wastes containing radionuclides discharged to surface waters if these waters would contain, at the point of discharge and prior to dilution, radioactive material at an annual average concentration greater than the DCGs (listed in Chapter III) for liquids. A DCG, by definition, is the concentration of a radionuclide in air or water that, under conditions of continuous exposure for one year by one exposure mode, would result in an EDE of 100 mrem (1 mSv). For multiple releases, the sum of fractions method is used where the concentration of each radionuclide is divided by its respective DCG, summed for each radionuclide, and compared to one (meaning the sum of fractions cannot exceed 1).

Several factors affect the BAT review, including the age of the facility; cost; and environmental, safety, and public impacts. At the present time, there is an exemption for tritium since no BAT is available. DOE issued an interim final report, DOE/EH-263T, *Implementation Manual for Application of Best-Available Technology Processes for Radionuclides in Liquid Effluents*, in June 1992 to provide guidance and explanation of the requirements for BAT effluent control found in DOE 5400.5.

To prevent the buildup of radioactivity in sediment, limits exist for the levels of alpha and beta-gamma settleable solids found in a liquid process waste stream released to natural waterways.

For gross alpha: <5 *picocuries per gram (*pCi/g) above background

For gross beta: <50 pCi/g above background

To protect native animal aquatic organisms, the absorbed dose from exposure to radioactive material in liquid wastes discharged to natural waterways must not exceed 1 rad per day. This limit is based on information contained in NCRP Report No.109, *Effects of Ionizing Radiation on Aquatic Organisms*.

The use of soil columns (trenches, cribs, ponds, drain fields, etc.) for retaining, by sorption or ion exchange, suspended or dissolved radionuclides from liquid waste streams, must be phased out and replaced by an acceptable alternative. Each facility is responsible for developing a plan and schedule for alternate disposal methods.

The BAT review process is implemented in some instances not just for liquid discharges to surface waters (as noted above), but also for releases to sanitary sewers where radionuclide concentrations, averaged monthly, would otherwise be greater than five times the DCG values for liquids (given in Chapter III) at the point of discharge.

In the codification of DOE 5400.5 to 10 CFR 834, total curie limits may apply. These limits (as stated in the draft version of 10 CFR 834) are:

- 5 Ci hydrogen-3
- 1 Ci carbon-14
- 1 Ci all other radionuclides

Compliance with the dose limits in the Order are demonstrated through documentation and recordkeeping, effluent monitoring, environmental surveillance, dose conversion factors, EPA-approved computer models, comparison with DCG values, and other methods with the approval of the Assistant Secretary for Environment, Safety and Health (EH-1).

Chapter III, Derived Concentration Guides for Air and Water

The DCG values listed in this chapter are provided as guideline reference values for conducting radiological environmental protection programs at operational DOE facilities and sites. DAC values for occupational intake of radionuclides through inhalation can be found in the appendices to 10 CFR 835).

DCG values are included for each of three exposure modes: ingestion of water, inhalation of air, and immersion in a gaseous cloud. Other potentially significant exposure pathways are not included in this chapter; therefore, specific pathway analyses would have to be performed for calculating public radiation doses.

Since the DCG values for internal exposure are based on a CEDE of 100 mrem, comparison with the DOE drinking water criterion of 4 mrem is accomplished by taking 4% of the DCG values for ingestion.

Chapter IV, Residual Radioactive Material

This chapter provides radiological protection requirements and guidance for the cleanup of residual radioactive material and the management of the resulting wastes, residues, and release of property. The criteria for cleanup of residual radioactive material used in this chapter originally applied to sites under the Formerly Utilized Sites Remedial Action Program (FUSRAP) and the Surplus Facilitiess Management Program (SFMP). These criteria now apply DOE-wide.

Residual radioactive material, as used in this chapter, includes residual concentrations of radionuclides in soil, airborne concentrations of radon progeny, external gamma radiation levels, surface contamination limits, and radionuclide concentrations in air or water resulting from or associated with any of the above.

The basic dose limit for the public from exposures to residual radioactive materials above natural background levels is 100 mrem (1 mSv) EDE. This limit applies to all sources and all release pathways from the facility or site in question. Separate limits apply to radon and its progeny.

For soil, residual concentrations of radioactive material are defined as those concentrations exceeding background concentrations when averaged over 100 square meters. Generic guidelines (i.e., guidelines independent of the property and that therefore apply to all facilities) are taken from existing radiation protection standards. For the radionuclides radium-226 (Ra-226), radium-228 (Ra-228), thorium-228 (Th-228), and thorium-232 (Th-232), these generic values are:

- 5 pCi/g averaged over the first 15 cm of soil below the surface
- 15 pCi/g averaged over succeeding 15 cm layers of soil more than 15 cm below the surface.

Site-specific release limits require a pathway analysis utilizing specific property data and the computer program *RESRAD*, which was developed by the Argonne National Laboratory. Hot-spot criteria also exist.

Limits for airborne radon decay products are taken from 40 CFR 192. The objective of the remedial action is to achieve an annual average (or its equivalent) of 0.02 WL, including background. In no case shall the radon progeny concentration exceed 0.03 WL (including background).

The limit for external gamma radiation (taken as an average level above background) is 20 µR/h inside a building or habitable structure on a site to be released without restrictions. This value similarly comes from 40 CFR 192.

Surface contamination guideline values, expressed in typical units of dpm/100 cm^2, are detailed in the table that follows. These guidelines were adapted by DOE from U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide 1.86, *Termination of Operating Licenses for Nuclear Reactors* (1974), and the NRC publication, *Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for By-product, Source, or Special Nuclear Material* (1982). The guideline values are applicable to existing structures and equipment.

Surface Contamination Guidelines

Allowable Total Residual Surface Contamination (dpm/100 cm^2)			
Radionuclides	**Average**	**Maximum**	**Removable**
Transuranics, I-125, I-129, Ra-226, Ac-227, Ra-228, Th-228, Th-230, Pa-231	RESERVED	RESERVED	RESERVED
Th-natural, Sr-90, I-126, I-131, I-133, Ra-223, Ra-224, U-232, Th-232	1,000	3,000	200
U-natural, U-235, U-238, and associated decay product; alpha emitters	5,000	15,000	1,000
Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above	5,000	15,000	1,000

The Order establishes authorized limits for residual radioactive material that should be set equal to the generic or DCGs unless it can be shown that the DCGs are not appropriate for use at the specific property.

Residual radioactive material must also be managed. DOE Order 5400.5 discusses several ways this can be achieved:

- Interim storage - Control and stabilization features shall be designed to provide for a minimum life of 25 years and an effective life of 50 years. Provisions for the control of Rn-222 and groundwater concentrations, quantities of residual radioactive material, site access, and use of onsite material must be established.
- Interim management - Generally applies when the residual radioactive material is in inaccessible locations and would involve a significant financial burden to remove.
- Long-term management - For uranium, thorium, and their decay products, control and stabilization features shall be designed to provide for a minimum life of 200 years and an effective life of 1,000 years. Control of Rn-222 emanation rates, groundwater concentrations, residual radioactive material, site access, and the use of onsite material must be established. The long-term management of other radionuclides is conducted under the provisions of DOE 5820.2A, *Radioactive Waste Management*.

Supplemental limits and exceptions can be requested in certain circumstances where the guidelines or authorized limits established for the site in question are not appropriate. Supplemental limits can allow uncontrolled release of the site without radiation restrictions; however, the basic dose limit of 100 mrem must still be achieved. Exceptions require that some restrictions be placed on the site (no farm use, for example). Any exceptions must be justified and ensure that the basic public dose limits are met. Control of residual radioactive material must still be established.

3. SELF-STUDY SCENARIOS/ACTIVITIES AND SOLUTIONS

Activity 1

You work for a management and operations (M & O) contractor and have been assigned the task of performing an internal audit to determine if your facility is meeting the requirements of DOE Order 5400.5. What factors would you address with respect to this document?

Activity 2

You work for a DOE contractor and your company provides science education in a small teaching facility using a limited number of radionuclides for instructional purposes. One of the sources used is tritium (H-3). Since you must dispose of the tritium, and since the amount you use in the course of a year is very small, you decide to dispose of it by simply dumping it down the drain.

How would you justify this action to a DOE auditor? Would you be permitted, under DOE regulations, to dump as much as 5.9 Ci of H-3 down your drain over the course of a year?

Activity 3

You have been tasked with assessing (revising) your site's environmental radiological protection program (ERPP). Meanwhile, 10 CFR 834, *Final Ruled,* has just been published. It varies little from the draft document (Part II). What factors would you consider in determining if your facilities ERPP program meets or exceeds the requirements of 10 CFR 834?

Activity 1, Solution
(Any reasonable paraphrase of the following will be acceptable.)

The contractor, and thus you, would be required to consider the following regarding DOE Order 5400.5:

- Are doses to members of the public in the vicinity of DOE activities evaluated and documented to demonstrate compliance with the dose limits of DOEOrder 5400.5 and to assess exposures of the public from unplanned events?
- Are collective doses to members of the public within 80 km of the site evaluated and documented at least annually?
- Are analytical models used for dose evaluations appropriate for:
  - Characteristics of emissions?
  - Mode of release?
  - Environmental transport medium?
  - Exposure pathway?
  - Ingestion of food?
- Are the following appropriately used in evaluating actual and potential doses in the environs of DOE facilities?
  - Information on dispersion
  - Demography
  - Land use
  - Food supplies
  - Exposure pathways
- Is such information updated as necessary to document significant changes that could affect dose evaluations?
- Are dose evaluation models that are codified, approved, or accepted by regulatory or other authorities used where appropriate (e.g., AIRDOS/RADRISK codes to demonstrate compliance with 40 CFR 61, Subpart H)?
- Are the appropriate tables (of approved dose conversion factors listed below) used to evaluate doses unless otherwise legally required?
- Is the dose delivered to a body over the lifetime of the individual from a single committed dose used for calculation of dose to the public?

- Are these conversion factors based upon the ICRP Reference Man model, and the committed dose integrated over an interval of 50 years?
- Are doses from exposure to external radiation from radionuclide concentrations in air and in water, and that result from submersion or from exposure to contaminated plane surfaces estimated, as appropriate, using the external dose conversion factors presented in EPA-520/1-88-020 and in DOE/EH-0070?
- Are DCG values presented as reference values for:
  - Inhalation of air containing the radionuclide?
  - Submersion in a semi-infinite cloud of air containing the radionuclide?
  - Ingestion of water containing the radionuclide?
- Are the DCG tables used to evaluate the three exposure modes upon which they are based?
- Are other methods and alternatives, other than those discussed above, used as prescribed in applicable regulations, submitted to EH-1 for approval?
- Are dose limits for members of the general public, from routine operation of a DOE activity, expressed as a dose received by the individuals during the year or the committed dose received by the individual over a period of 50 years from radionuclides taken into the body during the year?
- Are doses calculated as realistically as practicable? In other words, are the individuals subject to the greatest exposure identified, to the extent practicable, so that the highest dose might be determined?
- If dose limits apply to actual or committed doses of real individuals, do all factors germane to dose determination apply?
- Alternately, if available data are not sufficient to evaluate these factors, or if they are too costly to determine, are the assumed parametric values sufficiently conservative so that it is unlikely that individuals would actually receive a dose that would exceed the dose calculated using the values assumed?
- Are parametric values, used in performing dose calculations, recorded?
- Is the collective public dose in the environs of a site, with multiple emission points, estimated using the assumption that all emissions occur from a single point centrally located on the site?

- Is the assumption of a single point of emission, as discussed above, used to calculate public dose for the maximally exposed individuals if the emission points are close to one another relative to the distance to the site boundary? Otherwise, is the public dose to the maximally exposed individuals determined taking into consideration the actual locations of emissions on the site with respect to the offsite locations?
- What is the analysis required for each extraction (continuous monitoring and/or sampling) location and how often should each be conducted?
- What are the minimum detection levels and what is the degree of accuracy required?
- What are the quality assurance components?
- What are the effluent outfall alarm settings and bases?
- What is the significance of investigations and alarm levels?

Activity 2, Solution
(Any reasonable paraphrase of the following will be acceptable.)

You would have to maintain accurate documentation of how much tritium you actually use over the course of a year.

You would have to identify the maximum amount you would be able to dump down the drain and still be within the DOE guidelines.

You would then need to demonstrate that the amount dumped is only a small fraction of the amount you would be allowed to dump (under the Derived Concentration Guide values found in DOE 5400.5) and therefore, is justified under your facility's ALARA program.

No. The cutoff point for H-3 is 5.0 Ci/yr.

Activity 3, Solution
(Any reasonable paraphrase of the following will be acceptable.)

Does it include an ALARA program, and does it:

- Provide language supportive of the ALARA program?
- Describe how the ALARA program will be carried out?
- Discuss how to document ALARA decisions?
- Provide staff training to implement the ALARA program?
- Evaluate factors for:
  - Maximum dose to public (individuals)?
  - Collective dose to population?
  - Alternative processes (e.g., alternative treatments of discharge streams, operating methods, or controls)?
  - Doses expected for each evaluated alternative?
  - Cost of each alternative?
  - Comparison of all alternative costs?
  - Impact of each alternative on the public (e.g., differential doses from various pathways of exposure)?

Does it include a BAT plan relative to the use of the BAT for processing liquid waste (as per 10 CFR 834*)?*

- Does the BAT plan:
  - Discuss how to determine if a BAT is required?
  - If required, discuss the results of the selection process?
  - Provide a schedule for implementing the BAT, where selected?
  - Discuss the following factors that need to be taken into consideration (relative to technology, economics, and public policy) in making a choice as to which BAT is best?
    + Age of equipment/facility
    + Process employed
    + Engineering aspects of control techniques
    + Process changes
    + Cost of achieving such an effluent reduction

+ Impact on environmental nonwater quality
+ Energy requirements
+ Evaluate the effects of pollutants on the public and the environment?

- Utilize monitoring stations based on:
  + Type of emission?
  + Meteorology?
  + Climatology?pp
  + Topography?
  + Geography?
  + Population distribution?
  + Land use?
  + Other relevant considerations?
- Collect and analyze samples in a manner and frequency sufficient to characterize the emissions and effects of an activity?
- Verify unexpected and undetected releases?
- Provide meteorological data:
  + Representative of the atmospheric transport and dispersion conditions in the vicinity of the activity?
  + Including precipitation, temperature, wind speed, wind direction, and atmospheric stability that are important to surveillance?
  + Thata is supportive of routine and nonroutine emissions assessment?
- Provide a preoperational study that:
  + Begins at least a year before the start up of a new activity/facility?
  + Characterizes existing physical, chemical, and biological conditions that could be affected?
  + Establishes background levels of radioactive/chemical components?
  + Characterizes pertinent environmental and ecological parameters?
  + Identifies potential pathways for human exposure or environmental impact?

Has a waste plan been developed?

Does the waste plan:

- Address the management, disposal, and storage of radioactive wastes?
- Address low-level, high-level, and transuranic wastes as well as residual radioactive material?
- Comply with 10 CFR 834 and other applicable federal regulations?

- Describe:
  - The means used to limit access to wastes?
  - Interim and long-term strategies for dealing with waste?
  - Administrative safeguards?
  - Mechanism for cooperating with state and local officials in regard to wastes?
  - The process for releasing property contaminated or potentially contaminated with residual radioactive materials.

Has a quality assurance program been developed that includes:

- Organizational responsibility?
- Program design?
- Procedures?
- Field quality design?
- Laboratory quality control?
- Human factors?
- Recordkeeping?
- Chain-of-custody procedures?
- Audits?
- Performance reporting?
- Independent data verification?

4. SUGGESTED ADDITIONAL READINGS AND/OR COURSES

Readings

- 10 CFR 834*, Radiation Protection of the Public and Environment.*
- DOE/EH-0173T*, Environmental Regulatory Guide for Effluent Monitoring and Environmental Surveillance*.

Courses

- *Nuclear Physics/Radiation Monitoring* -- DOE.
- DOE/EH-0450 (Revision 0), *Radiological Assessors Training (for Auditors and Inspectors) - Fundamental Radiological Control,* sponsored by the Office of Defense Programs, DOE.
- *Applied Health Physics* -- Oak Ridge Institute for Science and Education.
- *Environmental Monitoring* -- Oak Ridge Institute for Science and Education.
- *Health Physics for the Industrial Hygienist* -- Oak Ridge Institute for Science and Education.
- *Safe Use of Radionuclides* -- Oak Ridge Institute for Science and Education.